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Resources of the urban factory

Definitions and findings from the *Urban Factory* research project

URBAN FACTORY
Entwicklung ressourceneffizienter
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Background

Cities account for a significant share of global value creation. The *Urban Factory* recognizes the advantages of urban production sites and finds resource-efficient solutions to meet current and future challenges. In this context, factories in urban environments offer a multitude of fields of action that open up efficiency potentials through synergistic use scenarios of resources. In terms of positive urban development and sustainable industrial development, city and factory enter into a constructive dialogue.

The research project *"Urban Factory – Development of Resource-Efficient Factories in the City"* creates methods and scientific foundations for this process by bringing together urban planning, urban development, industrial building, production engineering, logistics and energy design. Furthermore, existing urban-producing enterprises and urban structures are analyzed.

The resources of the urban factory and the city are fundamental to the consideration of the manifold material and immaterial interactions between them. An urban factory can only be understood in a functional and spatial context with the surrounding city and with the history of the location. An interdisciplinary approach is essential for the integration of factories into the urban fabric as a positive urban element.

Within the framework of the *Urban Factory* research project, eight resources are considered as key fields of action. These eight resources of the urban factory are defined in this document. The explanations are based on the following definitions of terms:

Underlying definitions

Resource
A resource comprises the means for performing an action or executing a task. It can be a tangible or intangible good. Every resource is bound to time and capital.

Exchange relationship
Exchange relationships are defined as the material or immaterial transfer of resources and the effects resulting from the use of resources. An exchange relationship affects all systems involved, regardless of the direction of the exchange.

Reference Framework
All resources and exchanges take place within a reference framework. This encompasses the spatial and functional system boundaries and includes the time and capital frames for action.

Resource efficiency
Resource efficiency means the careful use of resources in the sense that they are used to the greatest possible benefit. Efficiency as a goal means to achieve the highest possible benefit with the least possible effort.

Sustainable use of resources
The use of a resource is considered sustainable if the rate of use is not exceeding the rate of its regeneration or the viability of compensation in the providing system.

Resources of the urban factory

- Energy
- Knowledge
- Materials
- Justice & Culture
- Human
- Mobility
- Space
- Image & Appearance

Derivation

The resources of the urban factory were developed within the framework of the joint research project "Urban Factory - Development of Resource-Efficient Factories in the City" in transdisciplinary cooperation between representatives of different disciplines. The connection to practice was ensured by the inclusion of a project advisory board. Eight key resources were identified during the course of the project. These resources comprise the framework for action of urban factories. The identification and definition of the resources was carried out in an iterative procedure with a combination of deductive and inductive steps.

The systematics are based on the exchange relationships and interactions in the city-factory system (for example, space requirements and corresponding offers, noise emissions and absorption capacity or energy requirements and supply). Based on the reciprocal effects of an urban factory on the surrounding urban district and, in the opposite direction, of the urban environment on the factory, these exchange relationships were identified and summarized in workshops and working groups of representatives from the disciplines of production engineering, industrial construction, transport logistics, energy design and urban planning. The resources of the urban factory thus form the superordinate level of aggregation for the exchange relations between the urban factory and the city.

Included in the framework of the eight resources of the urban factory are time and capital. Each resource is related to these. In the context of the urban factory, the interaction of resources is not regarded as a resource in its own right, but is rather a result of the combination of different systems (e.g. biodiversity from space, materials, energy etc.). Materials and energy cover the environmental resources.

The resources of the urban factory serve as a connecting level, in which all mutual effects of the city and factory systems can be mapped onto each other. They provide a regulatory framework, form the basis for a structured and holistic analysis approach and enable the identification of cross-disciplinary measures to increase resource efficiency in the city factory system.

Energy

The resource energy is required to carry out all processes and actions. Energy can appear in different forms and can be transformed into another form of energy. This is usually necessary to provide useful energy from primary energy and is associated with conversion losses. The most common forms of energy are mechanical energy as potential or kinetic energy, electrical energy, thermal energy, chemical energy, nuclear energy and radiation energy. Energy cannot be created or destroyed in a closed system. Work is defined as the energy transmitted by a force. The physical quantity of power establishes the relation of energy to the temproal dimension. The efficient use of the resource energy by urban factories aims at the lowest possible energy input for desired, energy-consuming activities with regard to the city-factory system.

Energy forms the basis for all life on earth and is an indispensable component of human development. In general, any form of energy can be converted into another. Physical laws form the framework, which is described in particular by the fundamental laws of thermodynamics. The first main theorem describes the conservation of energy, which states that during the transformation from one form to another energy cannot be destroyed, but only be transformed. The second main theorem describes the effects of the principle of entropy on energy conversion. This means that in a system without influence from outside the system, energy always flows from the source to a sink. Here, one speaks between reversible and irreversible states. The third principle describes the equal distribution of energy, which means that energy (e.g. heat) in general, i.e. without additional external energy, tends to be distributed evenly within a system or between several systems [1].

The most common forms of energy in urban space are mechanical energy as potential or kinetic energy, electrical energy, thermal energy and chemical energy. Work is defined as the energy transmitted by a force. The work exerted or energy converted per unit of time is described with the dimension power. In real-world processes, only a part of the energy used is actually utilized to produce the desired result, as these processes are usually associated with losses. The ratio between the amount of energy that achieves the desired effect and the total amount of energy used is called efficiency.

The energy conversion chain - from primary energy to useful energy

When considering the theoretical demand or the concrete real demand of for instance buildings or means of transport, it is often divided in the four successive links of the energy conversion chain: primary energy, secondary energy and useful energy [2]. In particular, the useful energy in the form of technically usable mechanical and electrical energy represents the part of energy that can be converted or used without restriction in irreversible processes (e.g. electric heating). Thus, the useful energy represents a value that describes the energy demand or the balance of a physical-technical energy conversion process.

Fuels and raw materials are the starting point for the conversion of energy from material resources. They are differentiated according to their origin in fossil and renewable energy sources. Fossil energy sources are a finite resource in human time, as these resources and reserves are limited. A reserve is that part of a fossil fuel resource, which can be extracted economically using current technology. In addition to the conversion of energy from one form to another, the distribution or transport of energy from an energy source to an energy sink plays an essential role. Primary and secondary energy represent the two links in the energy conversion chain, taking into account the energy source used to produce the energy form. Renewable energy sources are sources of energy in various forms that are not exhaustible on a human scale. In contrast, fossil fuels are sources of various forms of energy that will no longer be available on the planet in a few decades or centuries at current levels of demand [3].

Renewable energies and the energy transformation

The term "energy transformation" was coined by the then German government after the nuclear reactor disaster in Fukushima. However, even before that, since the turn of the millennium, the restructuring of the energy supply in Germany has been pushed more and more concisely. In October 2014, the European Council also adopted a self-regulating climate and energy framework. For the EU member states, this framework represents a package of multifaceted goals, obligations, guidelines and more, which must be complied with and achieved by 2030. In order to achieve the politically ratified climate targets and to mitigate the additional financial costs associated with implementing the energy system transformation, the German government has repeatedly amended its energy research programs. Programs no. five and six in particular played a central role in this. Energy system transformation as a political objective is based on the use of alternative, renewable energy sources and innovative energy conversion as well as a restructuring of energy transmission and storage. The laws governing energy in mechanics and electrodynamics are complex however, and often exclude certain approaches from the start for reasons of economic efficiency. Physically, many solutions are generally conceivable, but the overall energy balances (e.g. energy input/output) of many conversion processes make little sense. The storage of electrical and thermal energy is of increasing importance in the context of energy systems. This also involves the conversion from one form of energy to another, for example from electrical energy to mechanical energy or thermal energy to chemical energy (latent heat storage).

Even greater energy savings can be achieved through more holistic energy system design and operation approaches at the neighborhood and district level. On these spatial scales, which go beyond the building level, solutions can be implemented that enable higher energy savings and more energy-efficient technologies. This is made possible by technical, operational and economic coupling of different forms of energy or different energy conversion plants. In addition, environmentally friendly and economic synergy effects can be achieved by coupling several buildings and urban elements. However, this often requires the restructuring of the infrastructure for the energy sources in mutual dependence or restructuring of the linkage of the sources and sinks of energy in the neighborhood. In this context, for example, the waste heat potential of different industrial processes could be used to cover the heat demand at lower temperature levels of neighboring urban functions.

Materials

The resource materials includes all physically and substantially existing things and in particular all materials that may occur in the context of the city-factory system. The resource materials contrasts with immaterial resources such as energy or information. Materials can be changed in their properties with the use of energy and can be viewed and used on different scales from the (sub-)atomic level to macroscopic material composites and are indispensable for the manufacture of physical products. They are used, transformed and converted as input streams in technical systems. Efficient use of the resource of materials is subject to the objective of reducing the specific material requirements of a production system and using material sources with the least possible impact. This can be achieved by circular systems and cascading use concepts with a coupling of a variety of urban system elements.

Of the three basic structuring groups of the world surrounding us - information, energy and matter - material matter is usually the most visible. This resource includes all materials that can exist in the context of the city and factory systems. All substances known to us consist of chemical elements on an atomic level. The atoms are constituted of the essential elementary particles protons, neutrons and electrons [4]. Materials can be classified according to various criteria, for example according to groups (metals, plastics etc.), functions/roles (auxiliary materials, raw materials etc.) or properties (liquid, solid etc.).

Material resources as the basis of the material environment

At the chemical level, matter is divided into heterogeneous mixtures and homogeneous substances based on its composition. Homogeneous substances may consist of pure substances or evenly submerged mixtures of different substances. At the lowest classification level, pure substances are differentiated into compounds and elements. Further (sub-)atomic divisions are not considered in the context of the resource materials in the context of urban factories. Materials can occur in one of three possible states: as gases, liquids or solids. These substances can be mixed together in different states, for example as a gas mixture, solution or alloy. In the context of urban production, heterogeneous mixtures of different elements and compounds are often considered. Buildings, infrastructure and solid products usually consist of a macro- and micro-mixture of different solids. Waste as well as gaseous and particulate emissions are also material and thus fall under material resources. Particulate emissions in the air are aerosols and are described as smoke (solid particles in the gas mixture air) or fog (liquid particles). A heterogeneous mixture of different liquids is called an emulsion [5].

Material resources can be distinguished according to their origin into biotic and abiotic resources. The terms biogenic and abiogenic are also frequently used. Biotic resources are converted by living organisms in biological processes or are required for these processes in significant quantities. Biotic resources also include raw materials and forms of energy that are produced by biological processes. These often include plant-based, renewable raw materials and materials of animal origin. In contrast, abiotic resources describe the non-living environment. These resources are used, for example, in chemical reactions that can take place without the influence of living organisms. Metals and minerals are examples of abiotic substance groups frequently used in ecosystems. Abiotic resources can also be used and modified in biotic processes.

In technical systems, material resources are used as input streams, processed and converted with the aim of obtaining desired output streams. In a factory, for example, these are transformed by system elements of the production system with the participation of energy, knowledge and work. In addition to the desired products, this also generates by-products, material and energy emissions, waste and new knowledge or information. Various methods of life cycle assessment can be used to evaluate the ecological effects of the use and emission of substances. A life cycle inventory contains all material and energy input and output flows for a technical system or product.

Materials and material efficiency

Construction materials form a significant group of material resources. These are substances that are used in products and infrastructure and for this purpose their properties are usually altered or changed using energy. These changes are achieved with conversion processes, which are referred to in production as manufacturing processes and divided into the main groups of forming, forming, cutting, joining, coating and changing material properties according to DIN 8580 [6]. The performance of materials is evaluated in terms of processability, strength, cost, safety and the associated environmental impact [4]. Based on their frequency of use, the most important material groups are metals, organic materials and mineral materials. These organic and inorganic materials can be found everywhere in urban areas. In the group of metals, steel is the most commonly used material in terms of mass, followed by aluminum and copper. Precious metals and rare earths are often used in electronic products, which are increasingly found in urban areas. Carbon-based plastics are counted among the organic substances. This category also includes materials such as paper, biotic resources and bitumen. One of the most common mineral materials is concrete and the associated concrete products. The mineral materials also include bricks, glass and other ceramics. Frequently used in urban areas, asphalt is a mixture of mineral and organic materials. Taking into account the resource space, the density and thus the volume requirement of material resources is also important. The use of secondary material is in many cases associated with lower environmental impacts compared to the extraction and processing of primary material.

Allwood et al. define material efficiency based on the goal of reducing material use for a given system (e.g. a product) while ensuring human well-being [7]. This means that the costs and environmental effects associated with the material requirement can be reduced or the output quantity can be increased without any negative effects from a material point of view. The motivation for increasing material efficiency is based on a variety of factors. Important drivers are the reduction of energy demand and emissions as well as other (environmental) effects through the use of material resources. Security of supply of important materials can also play a role. Energy is required to provide useable materials, for instance for extraction, processing and transport. This "energy contained in the material" is known as "embodied energy" and describes the average specific energy required per mass of usable material [7]. Closely related to this are the concepts of material effectiveness and material substitution.

Circular management and symbiosis

In order to achieve sustainable use of material resources, the focus is often on biological systems. In natural ecosystems, communities of living organisms exist in a stable state together with an abiotic environment. In this process, the waste products of a process or organism are used as raw materials by other living beings, so that a continuous use of the material resources is following a cycle. The orientation of economic concepts and methods on these principles is also called "bio-economy". Two concrete approaches to achieving sustainable use of material resources are, for example, the recycling of materials, which is legally anchored in Germany (and many other countries), or the (urban) industrial symbiosis [8].

Material resources can be recovered for use in the urban environment. One concept for this is "urban mining". Originally related to the recovery of materials used in buildings and infrastructure, an extension of the scope of observation to the concentration of products results in a high density of material resources in urban space, which can be used by urban factories for product generation. A city has not only built up resources, but also movable materials (e.g. precious metals and rare earths in used mobile phones) within the city limits. This extends the scope of urban mining by considering the whole city as a potential source of raw materials. For example, urban factories have the potential to procure materials needed to make new products from waste or end-of-life products.

Human

The functions of human activities and capacities that interact with urban production are designated as the resource human. These include in particular the functions as a labor force, for the generation of innovation and for consumption, which specifically enable production in urban environments. The aim of the efficient use of the resource human is to optimize the availability of workers and consumers in urban areas and to use it as a creative element for the creation of knowledge. In addition to this, the resource human in the sense of the neighborhood is also an important factor for the integration ability of production into urban space. On the one hand, human beings deserve protection and must be taken into account during production activities, for example by limiting emissions. On the other hand, the integration ability of production depends on the acceptance of the neighborhood, which is determined by various factors of the production system.

Human activity is a decisive force that determines development on our planet. The cities of the world are probably one of the most obvious and impressive manifestations of this. In recent years, there has been intense debate about whether humankind has ushered in a new earth age (the Anthropocene), as we have become the driving force behind biologic, atmospheric and geologic changes [9]. Satisfying human needs is the underlying reason for using natural resources, for example space and soil as living space or mobility. Thus, the resource human influences all processes and changes in urban space and is the carrier of innovation.

Citizens as a source of labor and consumption

Two decisive functions of the resource human for the urban factory are labor and consumption. The urban factory is dependent on the availability of workers with different qualifications to cover a variety of tasks. The demand for skilled workers in manufacturing companies will increase, especially for non-routine activities [10]. The resource human in the sense of the labor force is part of a regional and local labor market through which different qualifications are available. Due to the density of settlement, a comparatively high number of potential workers with a good average level of education is generally available in urban areas compared to rural areas. In a factory, people are required as a creative element to generate innovative solutions. A specific advantage of the resource human may be linked to the urban environment, since the innovation rate in cities is above the general average [11].

A second dimension of the resource human is consumption. The function as a consumer in the sense of a direct purchaser of products of industrial production is a dimension of this resource, which increases the economic efficiency of production by saving further resources through transport routes. In addition, the urban population can also be consumers of complementary services and infrastructure services that can increase the efficiency and utilization of the infrastructure. This can be achieved, for example, by purchasing process heat or using company-run kindergarten, canteens etc., which can improve the utilization of the industrial infrastructure. At the same time, by making factory functions available to the neighborhood, the image of the factory and thus its acceptance can be increased.

Stakeholders and interests

In addition to this, the resource human in the sense of the neighborhood is also an important factor for the integration ability of production into urban space. On the one hand, the human being is requiring protection and must be taken into account during production. Emissions from urban production sites (e.g. noise, fine dust, odors) must be limited to a tolerable level by means of limit values and immission control measures. On the other hand, the integration capacity of production depends on the acceptance of the neighborhood, which is determined by various factors of production. In particular, interactions with the resource image and appearance play an important role.

In the context of urban factories, there are a multitude of stakeholders whose interests are directly or indirectly affected by activities in the factory-city system [12]. The main stakeholders in this system at the spatial level of the factory are the company itself or the operators of the urban factory, the employees as well as technology providers for production and technical building equipment. The logistics providers and service providers for the realization of material exchange relations are affiliated to it. Outside the factory and in the immediate vicinity, the stakeholders are residents, residential and commercial owners in the immediate vicinity together with the members of a local value creation network. In increasing spatial distance, other stakeholders include external service providers and suppliers, residents of the district and the city in the immediate vicinity, and residential and commercial owners. In addition, local associations, political parties, interest groups and civil society groups play a role in the city-factory system, as well as social institutions and associations, providers of education or further training courses and organizations of the city administration. The economic interests of a city can be represented by an organized economic development agency. Furthermore, the authorities influence urban factories with medium and long-term urban planning and urban development, as well as regional and supra-regional administrative units, political stakeholders and interest groups. These manifestations of the human resource are of high importance for a resource-efficient design of urban factories.

Space

In the two-dimensional view, the resource space is represented as an area and describes the part of the earth's surface that can be used for different purposes. In particular, the sub-resource soil is considered in the urban system, which describes the uppermost layer of the earth's surface and in its natural form fulfils multiple environmental functions. The resource space comprises the available space in the three dimensions height, width and depth. In a city, space is indispensably required for implementing objects and activities, and there is often a conflict of objectives between different types of space use. A distinction is made between built-up and non-built-up space and between sealed and unsealed area. The value of space can be assessed in terms of location, usability and flexibility as well as quality and availability. The aim of efficient use of this resource is to fully exploit its potential in relation to the city's target functions. This is influenced by the possibilities for multiple utilizations and the factors of time and location. In the urban context, space as well as area is only available in a naturally limited way.

The part of the earth's surface that can be used for various purposes is considered as the sub-resource land or soil. Especially in an urban context, land is only available to a limited extent and requires efficient utilization. The value of the resource land is evaluated here in terms of its occurrence in relation to its location and the possibilities of its usability. The aim of efficient use of space is multiple use under the influence of the factor time and location. The resource space refers to usable three-dimensional space. In the urban context, space is generally as rarely available as the underlying land area. A distinction is made between converted and non-converted space. Its value is assessed in terms of its location and usability and flexibility, as well as the quality of its limitations. In order to make efficient use of this in the context of urban production, the area or space is a resource to be considered with care, the use of which - if possible - should be exhausted in terms of time and function.

In the resource definition for introducing resource efficiency in the European Union (EU), the resources "soil" and "physical space" are explicitly identified as fields of action [13]. The EU Commission defines soil as a resource and defines its use as a "medium for plant growth (...)", "home to many species of organisms (...)" and "sink for air and precipitation deposits (...)" [13]. In an urban context, the conservation of soil as a resource for these purposes is an objective of efficient management of this resource. Since 2004, the increase in land consumption in Germany has been declining, but the increase in settlement and transport area still amounted to 66 hectares per day in 2015 [14]. According to an extrapolation by the German Soil Protection Working Group (LABO), the degree of sealing of this area is just under 50% [15].

Use and function of surface and space

In the distinction between built-up and non-built-up space, as well as sealed and unsealed soil, different space classifications are generally available for various uses and different stakeholders. The urban functions of housing, production, retail, distribution, education and culture and recreation are dependent on areas with certain qualifications. The qualifications refer to the location of space and area as well as their dimensions and the underlying legal framework. The interaction and overlapping of functions can make efficient use of space, minimize land consumption and increase the value added per area.

In order to show the demand and supply of the spatial resources and to (re)assign them to the different urban functions, various representations can be used in cartography and planning depending on specific purposes. In two-dimensional space, maps and plans are a commonly used medium. Various elements are available for describing space, surfaces and thematic spatial information such as the decisive characteristics of urban space, the use of which can overcome the boundaries of the disciplines involved. In the context of urban production, this for example relates to the design of production sites, the general and surrounding development or density of the city, the available outdoor spaces, the underlying building law, the scale of the elements of urban development and the nature of the use of space. The available space has also to be seen as an economic factor and enabler for the production of goods.

In contrast to other building typologies (housing, trade, etc.), the full use of the resource space in the construction of production facilities cannot usually be uniformly implemented. Various factors, ranging from the product or the required type of production to the influence of customer needs, the desired image of the company or the regulatory framework conditions, exert an influence on the design of the factory system and thus on the buildings with specific requirements in terms of space and area. The frequently required interaction and combination of factories with other building typologies is made more difficult by very different building life cycles [16], constant conversion activities in/on the building or factory environment (growing/shrinking, logistical connection) or the necessary observance of distances to other buildings according to laws and environmental or safety regulations.

Evaluation of different potential types of use

For the determination of the degree of efficiency and an evaluation of the use of urban space, different target indicators are usually defined, which are often in conflict with each other. These targets can be of an economic, ecologic and social nature. For example, a Life Cycle Assessment can be carried out to determine the environmental effects of the use of space. This method can support the decision whether a specific plot of available space should be used for electricity generation by means of photovoltaics or for urban food production from an environmental point of view [17]. The target functions for an evaluation of spatial use can become very complex in the city due to the multitude of actors and uses (housing, recreation, value creation, etc.).

Knowledge

Knowledge is an intangible resource and consists of information and its relative interrelationships. Information respectively consists of structured data. The interaction of information with energy and matter describes all phenomena in the universe. Knowledge is seen as an indispensable means to perform an action, to execute a process or to solve problems. The available knowledge is decisive for the potential action alternatives. Knowledge is only present in humans, but it can also be stored symbolically, for example in writing, figuratively or acoustically, in order to expand memory by technical means. As a resource in the context of urban production, the targeted use of knowledge enables the solution of problems and is a prerequisite for innovation.

The basis for knowledge is information and its connections and dependencies. Information exists only in one system and requires a physical, chemical, biological or mental information carrier [18]. These always require a receiving system, in which the information carrier generates the information. This requires a triad of information carrier, receiving system and processor. The process of information usually occurs according to cause and effect over time and is particularly evident in technical systems. From the perspective of information theory, knowledge is static - except for learning processes that are able to change it. Only the use of knowledge can lead to impacts and effects. There is no knowledge as such present in devices, computers or robots. In contrast, these systems contain information carriers with the potential to produce effects [18]. Knowledge can be used (application) or changed (learning). It can be divided into implicit and explicit knowledge and must be distinguished from persuasion. Knowledge can also be transferred via a collective memory. In the course of time, information as well as its connections can alter, so that knowledge is subject to constant change.

Knowledge and knowledge-work

In the near past, a constant change in the demands of the nature of human work can be seen in a relative increase in non-routine and cognitive work tasks [10]. The term "knowledge worker" was coined in this context. Some characteristics of these knowledge workers are particularly important in connection with the resource human, as they are associated with the need for individuality and independence, autonomous decision-making and flexibility [19]. This can result in weaker ties to employers for employees, which urban-located companies can counteract by exploiting their specific advantages. These characteristics increasingly lead to the fact that more and especially younger people prefer a dynamic and thus more flexible life in urban areas, seeking and proactively influencing the immediate proximity to their individual networks (including the working environment). These structures maintain and create new knowledge or the persistent knowledge is permanently reviewed, discarded and supplemented or passed on to other individuals. These phases of change occur generally in cycles whose duration and influence vary continuously [20]. The knowledge of the individual in the network of the city moves or develops dynamically in new environments (social networks, modern forms of work, etc.) At the same time, societies strive to maintain traditional structures. These living environments enrich the creation of knowledge through reflection and recollection - but also hold potentials for conflict, especially for factories in urban areas. Studies show that the innovative capabilities in urban areas can be above average [11].

Many companies are hardly aware of the opportunities and risks described. In addition to their active roles within the company, employees can also take on the roles of neighbors, customers or policy makers, based on their knowledge of the factory environment and networks outside the factory. The efficient use of knowledge as a resource is severely hampered if the knowledge of the people in the neighborhood is not recorded and included in development processes. In this way, the growing knowledge about location factors and visions of the future can be formed and realized.

Justice and culture

The resource of justice and culture enables the socially guaranteed enforcement of claims and allows activities to be carried out within defined boundary conditions and frameworks. Justice consists of generally applicable rules of conduct and their concrete enforceability, which is a necessary condition. It is a part of the culture of a society. From a resource point of view, culture can be on a summarized level described as the existence of (social) competencies in urban society. These competencies can be utilized for activities and can have an impact at both the material and the immaterial level. At the same time, the implicit and explicit use of this resource defines the possible framework of action for urban factories.

In the context of urban production, the resource of justice and culture is divided into two partial aspects. While justice as a resource of the urban factory subsumes a multitude of existing written laws, regulations, norms and guidelines, it also exhibits the necessary condition of enforceability. Culture describes a sociological perspective on the city-factory system and outlines its application within this functional and spatial boundary. The starting point for this approach is generally the sociological (human) capital theory and in particular the theory of cultural capital founded by the French sociologist *Bourdieu* [21]. Cultural capital thus exists in an incorporated form, above all in the education of human beings, objectified in cultural goods such as pictures, books, instruments or machines or institutionalized, for example in school degrees or titles. *Wippler* transfers the incorporated cultural capital into the existence of cultural competencies, which are also a prerequisite for the use, creation or acquisition of objectified and institutionalized cultural capital [22]. According to this, cultural competencies are the "mastery of aesthetic, linguistic-cognitive and social codes" - a mastery, which opens up possibilities of interaction for the stakeholders and enables a relatively smooth flow of social relations. Within this frame of reference, cultural competencies and cultural resources can also be classified as a basis for the creation and use of relationship networks for a stakeholder’s purposes. The existence and use of such relationship networks can be described as a social resource. For urban factories and their embedment in the city-factory system, culture is thus a fundamental resource due to the exchange relationships, the necessary cooperation and the cross-interface perspective of action.

Justice as the basis of the framework for operationalization of urban production concepts

There is a considerable number of standards, laws and guidelines which are applied in the context of interdisciplinary consideration. Laws, standards and guidelines have, depending on their type, a binding legal character or can be given a binding character as recognized sets of rules or regulations. For example, in the context of mobility, the city acts as a territorial authority within the framework of infrastructure law or prescribes it, depending on the constituency. In particular, laws and guidelines on the planning, maintenance, construction, expansion and financing of transport routes and facilities must be observed [23]. All other players in the city-factory system operate in this example within the framework of traffic law, which includes, among other things, the road traffic regulations and licensing regulations. If the codes of conduct are broken by any stakeholder, this is enforced with predefined consequences.

Standards, laws and guidelines can be differentiated according to their relevance in terms of administrative rules for site and operation approval as well as construction engineering and those applying in the design of the planning process. With regard to approval procedures for urban factories, the (non-harmonized) building regulations of nations and even federal states or city governments, the building regulations and the industrial building guideline, but also Energy Saving Ordinances (as for instance EnEV), workplace directives and, if applicable, the Federal Immission Control Act (BImSchG) are of particular importance. They form the legal basis for the design of the planning object and must always be reflected in terms of content at an early stage in the planning process in order to avoid subsequent adjustments and costly structural solutions or even time delays. Especially in an urban context, the approvability of production systems and factories is often seen as a major hurdle in the construction of new urban factories and the operation of existing ones. With the resource of justice and culture, a balance can be created between the stakeholders involved in the city-factory system.

Mobility

Mobility enables the spatial transformation of material and immaterial objects through movement. The transport of people and goods is made possible by a mobility infrastructure. Immaterial things, such as energy, also require a material infrastructure for targeted spatial mobility (transmission). Various performance parameters can be considered to assess the quality of mobility. There is a high, spatially concentrated demand for mobility in urban areas. An efficient use of the resource mobility aims at the lowest possible expenditure and associated negative impacts for necessary spatial changes.

Mobility manifests itself in different dimensions and levels [24]. The perspective of potential mobility, which determines whether and which forms of mobility are possible, sets the framework of these dimensions. The counterpart of potential mobility is realized mobility, which describes the actual design and operationalization of potential mobility. Against this background, mobility can be divided into social and spatial dimensions. While social mobility defines the ascent and descent along strata (vertical) or, for example, the change of occupation (horizontal), spatial mobility is differentiated in terms of time into everyday mobility (short-term) and residential mobility (long-term) [25]. The spatial mobility of people can further be divided into individual transport and public transport.

The spatial mobility of people described in this way can also be adapted and transferred to goods or logistics. The single-purpose transport of goods is carried out at short notice in the temporal sense. Goods are transported in the procurement, production and distribution phase from the place of availability (source) to the place of demand (sink). These transport process flows can be broken once or several times due to handling, change of means of transport or temporal storage. Depending on the duration of storage, a transport process can be understood as a longer-term, spatial mobility of goods; an example of this would be the decentralized distribution and stockpiling of a range of goods within a sales region. The mobility of data, information and (where feasible) knowledge can also be seen as an aspect of spatial mobility. To this end, a distinction can be made between the availability or presence of data, information and knowledge (potential mobility) and the transmission or dissemination (realized mobility).

The basic forms of mobility

The basic forms of mobility can be anthropocentrically summarized in the subdivisions of individual transport ("I drive"), public transport: ("I am driven"), freight transport/logistics ("I let drive") and data (information and communication technology, "I stay") [26]. Each of these forms of mobility is in turn based on resources. Firstly, spatial mobility requires transport infrastructure. Transport infrastructure in the broader sense refers to the material, personnel and institutional prerequisites for transporting people, goods, energy and data. In the narrower sense, transport infrastructure consists of all fixed installations such as natural or built transport routes and their access and transfer points. The mobility of people and goods also requires means of transport. Means of transport are facilities that move people or goods [27]. The interaction of transport infrastructure and means as a system is also referred to as a mode of transport [28].

Mobility itself, in its four basic forms, can be considered a resource. Mobility is an expression of "people's need for participation and exchange" [29]. Thus, mobility can also be understood as a need derived from other needs and thus as a resource of social and economic life. Mobility of people, goods, energy and data enables and supports social, cultural and political participation, education, supply, trade and economic exchange processes.

Mobility from the perspective of the city-factory system

From the point of view of the factory, mobility enables the supply of material and immaterial input and its disposal. The factory is supplied with raw materials, auxiliary materials, semi-finished products, machines, etc. for production by freight transport. In addition, freight transport takes over the distribution of the products and the disposal of other material output such as waste. Passenger transport (individual and public transport) brings employees, suppliers, customers and visitors to the factory. They are carriers of knowledge and contribute their skills and abilities. In addition, the factory is supplied with data and furthermore with energy and raw materials via carrying systems. From the perspective of the factory, mobility enables the economic activity of production.

Two perspectives can be distinguished for the city. The city as a local authority pursues the goal of enabling low-cost, efficient, safe and environmentally friendly mobility. This involves the provision of transport infrastructure, institutional and organizational framework conditions and public transport services. One field of action for the city is thus the potential mobility of people and goods. Within this framework, urban society, businesses and all urban actors are set mobile for private and social purposes and for the provision of economic services. They realize mobility within the given framework of the city and pursue the goal of low-cost, efficient, safe and environmentally friendly mobility. Here, the city's stakeholders compete for transport infrastructure and transport services with the traffic induced by the factory. Against this background, efficiency of the resource mobility in the sense of the Urban Factory demands the suitable design of the mobility for factory and city to satisfy the respective needs within the infrastructural, organizational and legal boundary conditions of the city.

Image and appearance

Image is understood as the effect of entities and objects on human consciousness and the associations connected with them. It is an emotional, immaterial resource and indirectly influences the creation of actions and effects. Image can be influenced by the formulation of self-images and strategies (e.g. "Vision & Mission"). In connection with the appearance of a product, a building, a company or a person its identity results in strong connection with the specific shape. Identity is essentially determined by the four elements of behavior, symbols, services and communication. As an emotional, immaterial resource, image indirectly influences the generation of actions and effects and is therefore important for the efficiency of a company's activities in the city factory system.

Image and appearance can be used as an immaterial resource in the context of urban factories to enforce the interests of both companies and urban stakeholders. Identity can be seen as the basis, which is essentially determined by the combination of the four elements of behavior, symbols, services and communication [30]. The stakeholders (in this case companies and the city each as combinations of numerous system elements) transfer their identity to their surroundings both indirectly and directly via interaction, thus influencing their image ("image / impression") in a variety of ways. The term image is thus understood to refer to the effect of the respective stakeholders on the human consciousness about entities and objects and the associations connected with them. In relation with the shape, conclusions can be drawn about the identity of a product, company, place or person [30]. In the context of the integration of production sites into the quarters of the urban fabric, image as a resource and specifically the influencing factors determined by design play a decisive role. They have an effect on the neighborhood or city from within the company and can also have an effect on the company from within the city.

Companies are generally aware of the potential of a "good image". Citizens in the neighborhood, customers, investors or employees potentially perceive a company very differently. Image building can be considered a highly complex and very dynamic process. The image can be developed, established and maintained over the long term, for example, by manufacturing a product with a positive identity or by developing a positive marketing strategy [31]. Changed production methods (e.g. additive manufacturing, modular desktop machines, distributed value-added networks), the return to crafts and the positive perception of the use of regional resources have led to new products, company structures/sizes and networks in recent years and are shaping urban structures in a different way. A visible example is the maker movement, which manifests itself spatially in Makerspaces and FabLabs and has built up its own image in the process.

Every building in urban space, thus including urban factories has a special role as an interface between different spatial segments. The fact that a deep, complex interaction can arise through the loyalty of employees and customers increases the importance of the resource image or appearance of the factory in the urban context. The image of a company is expressed and thus transferable to the urban environment in many ways, e.g. through the visibility of the product or the design of the production facility in the neighborhood. *Schalcher* describes buildings in terms of their function as subject, object and means of communication [31]. The structured development of a "communication concept" in relation to target groups is important, as this can convey values and messages. An appropriate, positive architecture can link the resource image and appearance with the resources people and knowledge. An urban factory becomes part of the building culture in the city.

On the urban development level, the preservation or settlement of a company with a high image value can provide a variety of advantages. The charisma of the company can induce other companies to settle/locate here or to expand their product range and product-quality or initiate networking with other stakeholders in a city (universities, service providers, etc.). Companies and cities can use their identity to strengthen and positively exploit uniqueness [32].

Municipalities and especially their business development and city marketing agencies are facing economic challenges. It is important to bind companies of all sizes, from start-ups, medium-sized hidden champions to global players to their local site, and to pay attention to aspects such as expansion, reduction of relocation, mobility, innovative communication structures or a good environment for highly qualified specialists [33]. The structured investigation of the image value of both the companies and the individual neighborhoods/cities enables targeted improvements and efficiency gains along specific needs of the companies and neighborhood/city.

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Further publications from the Urban Factory project

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